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PULSE COUNTING CHRONOMETER FOR SHOCK-WAVE MEASUREMENTS

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ABSTRACT: A pulse-counting device which can be used for directly determining the time intervals between pulses produced by shock-wave pressure and speed sensors positioned along the path of a shock wave in a shock tube or other shock-wave system is described. This chronometric device is designed to provide immediate information on the operation of such systems, without the time and labor that other available techniques require in treating photographic materials.

A large number of problems are being studied in devices which use shock waves in gases, in relation to which the state of the gas behind the shock wave is calculated from the laws of conservation according to the initial pressure in front of the shock wave P_0, which is measured in each experiment, and according to the speed of the shock wave V_0. /154*

In most of these studies, the speed of the shock waves are determined by recording the change in pressure, temperature, or illumination in a shock wave when it passes by sensors [1]. The pulses from two sensors positioned along the path of the shock wave are recorded by an oscilloscope or a chronometric device of the IV-13M type. The average speed is calculated according to the time interval between the pulses and the distance between the sensors.

A determination of the time interval according to the sweep of the oscilloscope or chronometric device is linked with the development of the photographic materials and their analysis under a microscope. Thus, the process of the experiment is substantially disconnected in time from the process of the researcher's obtaining information concerning the operational regime of the device during the experiment.

In order to eliminate this shortcoming, there has been a great deal of laboratory experimentation in designing instruments which permit obtaining the numerical value of the time interval between pulses during the process of the experiment [2,3].

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* Numbers in the margin indicate pagination in the foreign text.

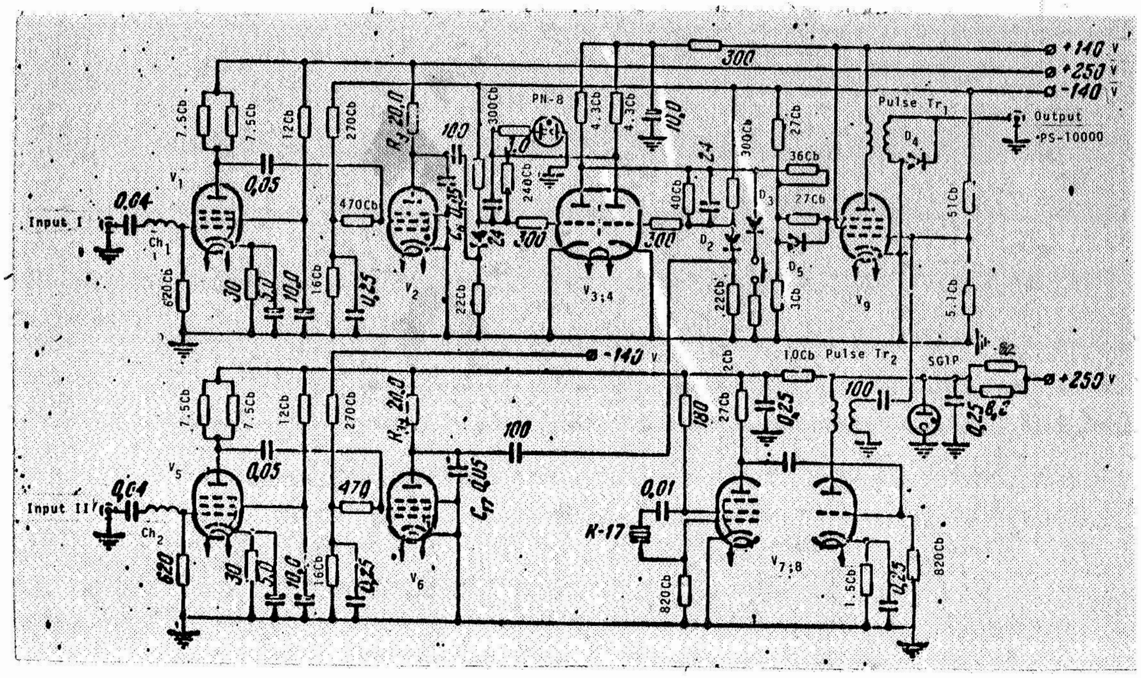

Fig. 1. Principal Schematic Diagram of Pulse-Counting Chronometer

Piezoelectric transducers which were designed in our laboratory [4] are now being used in the capacity of a pulse-counting chronometer, and the pulse counter we use in this case is the standard scaler of the PS-1000 type. /155

The chronometer operates by counting the number of pulses with a frequency of 1 MHz which arrive within the time interval between two pulses from the piezoelectric transducers; it is a two-channel electronic shaper of the pulses from the piezoelectric transducers into rectangular pulses, which are equal in length to the time interval between the leading edges of the pulses from these sensors.

The principal schematic design is shown in Figure 1. The voltage diagrams (by blocks) of this design (Fig. 2) clarify the operational procedures of the blocks and their functions.

The signals from the sensors [Fig. 2(a)] which are at the separating inputs of Channels I and II open up the thyratrons of the shaping blocks [Fig. 2(c)] by their leading edges after amplification in the first cascade [Fig. 2(b)]. As a result of the use of thyratron shaping, the instrument effects a single operation during the time of the discharge and pileup of the capacitance charge $C_{6,17}$ at the anodes V_2 and V_6. This time is regulated, by a proper selection of $R_{8,39}$ and $C_{6,17}$, so that it is much longer than the time for a signal from the piezoelectric sensor, i.e., the time for

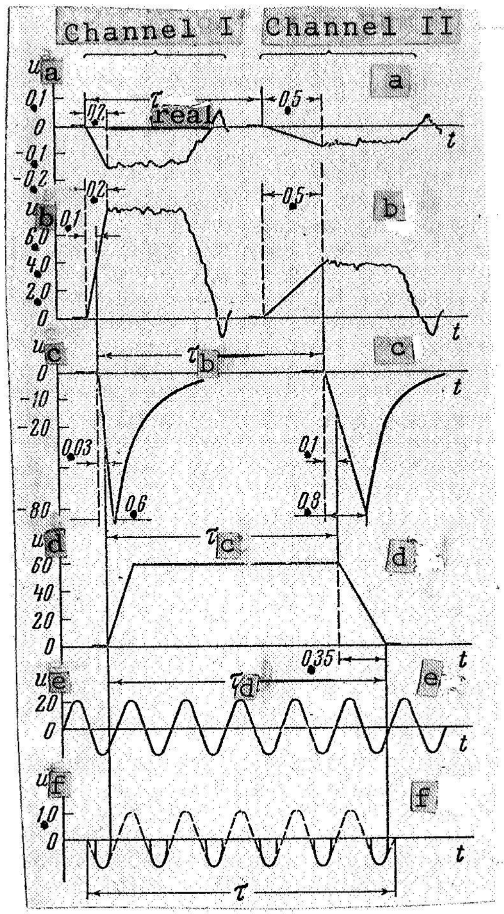

Fig. 2. Voltage Diagrams at the Input of the Device and at the Outputs of the Cascades. (a) Shape and Characteristics of the Signals of the Piezoelectric Pressure Sensors; (b) Amplifying Cascades (V_1 and V_5 - 6E5II); (c) Pulse-Shaping Cascades (V_2 and V_6 - TGI-0.1/1.3); (d) Trigger (V_3 and V_4 - gNgII); (e) Regulated Generator (V_7 and V_8 - 6F1II); (f) Coincidence Circuit (V_9 - 6Zh2II).

attenuation of the wave processes in the shock tube. On arriving at the trigger [Fig. 2(d)], the signals from the thyratrons alternately open it up (Channel I) and cut it off (Channel II) with their leading edges. A rectangular voltage pulse arises at the output of the trigger and opens up the coincidence circuit [Fig. 2(f)]. At this moment, the coincidence circuit becomes passable for sine-shaped oscillations with frequences of 1 MHz coming from the generator. This generator is regulated by a quartz resonator of the K-17 type [Fig. 2(e)]. Negative pulses of a duration of 0.4 μ sec and repetition frequency of 1 MHz are obtained at the output of the coincidence circuit and recorded by the PS-1000 scaler.

Measurement Errors

The systematic error of a pulse-counting chronometer with an internal generator is determined by the magnitude of the noncorrespondence of the real frequency of the generator taken for the frequency reading.

This noncorrespondence depends mainly on the tuning precision of the generator and the temperature coefficient of the frequency drift. For a generator with shock-wave excitation of oscillations, the tuning becomes a rather tedious matter, and requires a very precise apparatus. /156

Therefore, we selected the design of a generator which is regulated by a high-precision K-17 quartz resonator.

The K-17 quartz resonator has the following parameters: natural frequency $f = 10^6$ Hz$\pm$7 Hz; temperature coefficient, $+1.0 \cdot 10^{-6}$ Hz·degree^{-1} in the range from 20 to 50°. With these parameters of the quartz, an error of 1 μ sec is possible in measuring a time interval of 10^6 μ sec, because of the difference of $\pm$7 Hz between this frequency and the calculated one. The systematic error due to a change in the temperature of the crystal up to 50° is less than +1 μ sec for each second of the measured time interval. No special means were taken in this case to stabilize the temperature of the quartz resonator, except for removing it from possible sources of heat. The measurements showed that the temperature of the chassis near the resonator did not exceed 40° C. This gave us the basis on which we could assume that the errors of the generator in measurements of time intervals up to 10^3 μ sec could be disregarded.

Random errors of the chronometer are determined according to the stability of the cascade signals, both in voltage potential and in duration of the leading edge, since the cascades of the device trigger the input pulses from the leading edges (see Fig. 2).

The piezoelectric transducers for the triggering of both channels of the chronometer eliminate untimely actuation of either channel.

The random error for this circuit is determined by the ratio between the input voltages and the triggering thresholds in stages, as well as by the discrepancy in the durations of the leading edges of the input voltages.

In determining the error, the triggering threshold of each cascade is calculated according to the technological characteristics of the tubes used. The power bands of the transducers, which depend on the regime in the shock tube, are measured with the aid of a cathode-ray oscilloscope, the IO-4.

The deviation in the durations of the leading edges are measured by determining the input voltages by stages.

As for the first amplifying cascades of both channels, it was understood that they transmit the leading edge of a pulse form the sensor without distortions, since the pass band of the amplifier is 5 MHz, which is much greater than the frequency corresponding to the leading edge of the input pulse (about 3 MHz).

For the shaping block, the thyratrons were identical in triggering threshold. The possible deviation in the potentials from the sensors was ±25%. In this respect, the duration of the leading edge depended on the speed of the shock wave V_0, and varied from $0.35^{\pm 0.15}$ to $0.15^{\pm 0.1}$ μ sec for V_0 = 1000 and 4000 m/sec, respectively. The time τ_{real} between the beginnings of the leading edges of the pulses at the input of the amplifiers of both channels was taken as the real time. These pulses pass through the amplifying cascade without distortions. Since all the subsequent blocks actuate the input pulses from the leading edges, the delays in the actuation of the first channel produce a negative error, while those of the second channel produce a positive error.

The variations in the delay for both channels are determined, not only by the duration of the leading edges t, but also by the ratio k between the output voltage of each cascade and the triggering threshold of the subsequent cascade.

Thus, the absolute error, for example for the shaping cascade, is expressed in the following way:

$$\pm\Delta\tau = \pm\Delta\tau_{a} - \frac{t_{Ib} \mp \Delta t_{Ib}}{k_{Ib}} + \frac{t_{IIc} \pm \Delta t_{IIc}}{k_{IIc}},$$

where the subscripts a,b,c, etc. are the cascades; subscripts I and II are the channels of the design t is the duration of the leading edge of a pulse Δt is the deviation in the duration of the leading edge; $k = U_{in}/U_{th}$, where U_{th} is the triggering threshold of the cascade and U_{in} is the voltage at its input. /157

Let us write the expression for the absolute error of the blocks, from the amplifying to the trigger cascade, and then let us examine the effect on the error of the shortness of the measured time interval for the period of oscillations of the generator.

The absolute error for the cascades from a to d is the following:

$$\pm\Delta\tau = \pm\tau_{a} - \frac{t_{Ib} \mp \Delta t_{Ib}}{k_{Ib}} + \frac{t_{IIb} \pm \Delta t_{IIb}}{k_{IIb}} - \frac{t_{Ic} \mp \Delta t_{Ic}}{k_{Ic}} + \frac{t_{IIc} \pm \Delta t_{IIc}}{k_{IIc}} - \frac{t_{Id} \mp \Delta t_{Id}}{k_{Id}} + \frac{t_{IId} \pm \Delta t_{IId}}{k_{IId}}.$$

When $\Delta\tau_a = 0$ and the values of t, $\pm\Delta t$ and k are those presented in the Table for V_0 = 1000-4000 m/sec (respectively), we can calculate the values of $\pm\Delta\tau$.

TABLE

Cascade	Sign of Error	t, μ sec: $V_0 = 1000$ m/sec	t, μ sec: $V_0 = 4000$ m/sec	Δt, μ sec: $V_0 = 1000$ m/sec	Δt, μ sec: $V_0 = 4000$ m/sec	Ch_1	Ch_{11}
b	+	0.35	0.15	0.15	0.1	2.0	1.0
	−					1.0	2.0
c	+	0.7	0.7	0.1	0.1	5.35	5.35
	−						
d	+	0.25	0.25	0.1	0.1	∞	1.0
	−						

Since the duration of a rectangular pulse from the trigger is considered as the time between the appearance of the beginning of the leading edge and the end of the trailing edge, $t_{Id} = 0$. The values presented above, which were measured for a large number of experiments, permit us to calculate the following for shock-waves speeds from 1000 to 4000 m/sec:

$$\Delta\tau_{max} = \begin{cases} +(0.788\text{—}0.612) \\ -(0.287\text{—}0.112) \end{cases} \mu\text{ sec}$$

Considering that the electronic "value" (Cascade f) is open the entire time from the beginning of the leading edge to the end of the trailing edge of a trigger signal, as well as the fact that only the negative part of the sine-wave of the generator is transmitted in the PS-1000 device, we can expect that there will be a difference between the measurable and measured time of one pulse in the scaler, for a maximum random error of $\Delta\tau_{max} = \begin{cases} +0.788 \\ -0.287 \end{cases}$ μsec, since $\Delta\tau_{max} < T$ is the period of the oscillations of the generator.

Thus, for any measurable time interval, the maximum possible random error is ±1 μsec. The relative error δt in this case is a value connected linearly with the measurable time, and is equal to 1% for an interval of 100 μsec.

REFERENCES

1. Sb.: Udarnyye truby. (Collection: Shock Tubes), ed. Kh.A. Rakhmatulin and S.S. Semenova. Foreign Languages Publishing House, 1962.
2. Boronin, A.P. and T.G. Ignat'yeva: Impul'snyye zondovyye izmereniya v udarnoy trube. (Collection: Pulse Probing Measurements in Shock Tubes), in: Sb.: Fizicheskaya gazodinamika i svoystva gazov pri vysokikh temperaturakh (Physical Gas Dynamics and Properties of Gases at High Temperatures). Moscow, "Nauka", 1964.
3. Kabanov, G.L.: Izmereniye skorosti udarnykh voln v razryazhennykh gazakh. (Shcok-Wave Speed Measurements in Rarefied Gases), in: Sb.: Fizicheskaya gazodinamika i svoystva gazov pri vysokikh temperaturakh (Collection: Physical Gas Dynamics and Properties of Gases at High Temperatures). Moscow, "Nauka", 1964.
4. Gusev, M.V. and O.I. Luneva: P'yezoelektricheskiy datchik davleniya. (Piezoelectric Pressure Sensors), in: Sb.: Issledovaniya po fizicheskoy gasodinamike (Collection: Studies in Physical Gas Dynamics). Moscow, "Nauka", 1965.

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